North Pacific Acoustic Laboratory (NPAL) – Towed Array Measurements

Kevin D. Heaney
Ocean Acoustical Services and Instrumentation Systems (OASIS), Inc.
5 Militia Drive
Lexington, MA 02421
phone: (781) 862-8339   fax: (781) 862-0572 email: heaney@oasislex.com

Award Number: N00014-07-C-0171
http://www.oasislex.com

LONG-TERM GOALS

The long-term goal of this research is to understand deep-water propagation, with particular emphasis placed on the passive quiet target detection problem. Focus is on the spatial/temporal structure of acoustic paths for moving sources and moving receivers. Propagation paths are separated into two classes: bottom interacting and refracted/surface-reflected (non-bottom interacting). This research seeks to understand the impact that mid-ocean variability (internal waves, mixed layer variability) and seafloor scattering have on the detection problem.

OBJECTIVES

The objectives of the FY09 effort were to model and measure acoustic signals for a set of propagation paths using multiple sources. The sources included an axial moored source, a ship towed shallow source and a ship suspended axial source. Specific scientific objectives are: to develop an understanding of the sensitivity of the structure of the convergence zone to ocean meso-scale variability; to investigate the structure and spatial variability of bottom bounce acoustic paths; to develop an understanding of the sound field behind a ridge or seamount. A final objective is to determine the feasibility of performing moving ship tomography (MST), requiring high-resolution array element location.

APPROACH

The approach was to conduct a preliminary experiment in the Philippine Sea (NPAL PhilSea09) as an engineering test prior to the larger scale experiment in FY10. Numerical modeling was performed to determine source receiver geometries that permitted the investigation of the spatial/temporal structure of particular acoustic paths. Recordings where then made on the ONR Five Octave for Research Array (FORA) of sound transmitted from 3 sources (a moored axial source, a ship suspended source MPX200 and a ship towed source-J15).

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE **North Pacific Acoustic Laboratory (NPAL) Towed Array Measurements**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Ocean Acoustical Services and Instrumentation Systems (OASIS), Inc,5 Militia Drive,Lexington,MA,02421**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The long-term goal of this research is to understand deep-water propagation, with particular emphasis placed on the passive quiet target detection problem. Focus is on the spatial/temporal structure of acoustic paths for moving sources and moving receivers. Propagation paths are separated into two classes: bottom interacting and refracted/surface-reflected (non-bottom interacting). This research seeks to understand the impact that mid-ocean variability (internal waves, mixed layer variability) and seafloor scattering have on the detection problem.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

The PhilSea09 experiment was successfully conducted this spring (May 2009). The FORA array was successfully deployed for over 18 days (Dr. Kyle Becker, ARL-PSU) from the R/V Kilo Moana (Chief Scientist, Professor Arthur Baggeroer, MIT). Recordings of the Scripps Tomographic Source (deployed by Dr. Peter Worcester, SIO), the ship towed J15 (deployed by Dr. Gerald D'Spain, SIO) and the ship suspended MP200 and HX554 (deployed by Dr. Jim Mercer, APL-UW). Source receiver geometries included spanning a convergence zone (CZ), long-range propagation (2-3 CZ's out to 200 km), scattering from a seafloor ridge and near source bottom bounce propagation.

Four of the significant geometries are shown in Fig. 1. In order to measure the range-structure of the CZ, a geometry was devised to permit multiple CZ crossings through different water masses with a minimum amount of turning of the ship and array. The source-receiver distance spanned the ranges of 45 to 70 km, permitting measuring of the field across the 55 km CZ. The geometry, also known as the "Star of David", was conducted 2 complete times for two different sources in different locations. The upper right panel shows the closing geometry as well as a constant range arc. The closing geometry was designed to keep the S35 stationary ship source off of the forward endfire beam. The range arc provided over 12 hours of continuous nearly constant (within 100 m) range between the source and receiver within the convergence zone. The lower left panel shows the long-range linear tow. This run covered ranges of 50 to 300 km from the T1 tomographic source, which was transmitting every 5 minutes. During the tow, the R/V Melville towed a source in the opposite direction yielding measurements of 1 and 2 CZ as well bottom bounce paths within a CZ. The lower right panel shows an ambient noise pentagon, recorded over 24 hours when there was no active source in the water. Of scientific interest is the impact of the deep-water ridge (which rises to 2400 m) on the ambient noise directionality.

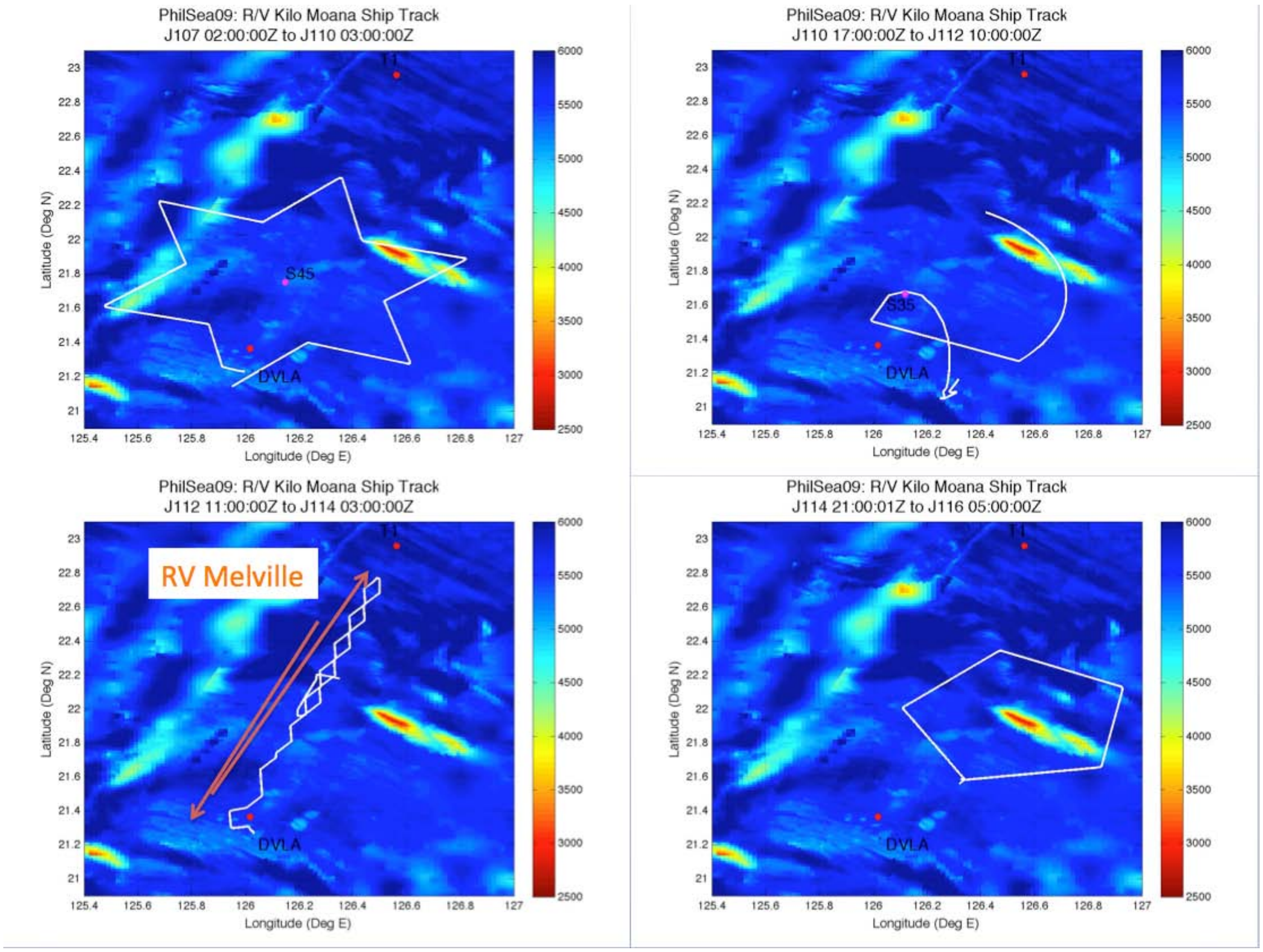

Figure 1. PhilSea 09 Geometries. Upper left: Convergence zone "Star of David" around S45 ship suspended source. Upper right: Bottom bounce and fixed range arc around S35 ship-suspended source. Lower left: Long range radial from T1 and passing of towed ship suspended source. Lower right: Ambient noise pentagon around a bathymetric ridge.

Two papers[1, 2] were published in the Journal of the Acoustical Society of America (JASA) by Heaney during the FY09 period of performance. One paper was submitted to the Journal of Computational Acoustics.

RESULTS

Only preliminary analysis of the experimental data has been done to date. A quality analysis of the data has revealed that there are data-glitches affecting the timing of the data on up to 5% of the recordings. In spite of this the overall data set is high quality with successful horizontal line array measurements taken in a wide variety of deep-water geometries. This sort of research-community available deep-water acoustic measurements (with a towed array) is rare. As an illustration of the various types of data, three figures are presented. In Fig 2 a frequency-azimuth (FRAZ) plot is shown with the ship suspended J-15 source at a range of 1 CZ near broadside. A 4 second FFT has been conducted with an incoherent integration time of 2 minutes. The narrowband lines of the source transmission are clearly seen at 10 degrees azimuth. The ownship noise of the R/V Kilo Moana is visible at 80-90 degrees (forward end-fire in this figure).

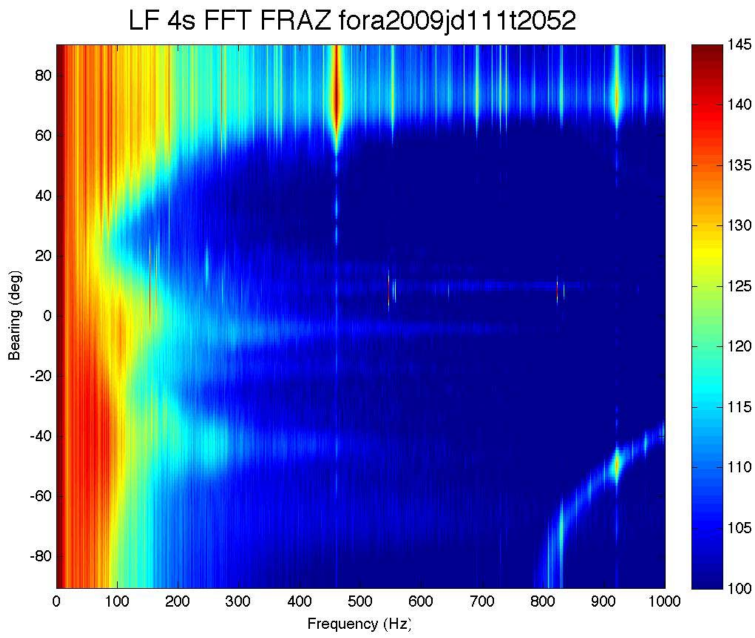

Figure 2. Frequency-Azimuth (FRAZ) plot of beamformed response from FORA during CZ tow. The narrowband tones of the ship-suspended source are visible at 10 degrees off of broadside.

During the S45 "Star of David" run the R/V Kilo Moana received transmissions from the tomographic source T1 every 3 hours. One of these receptions had the deep ocean ridge between the source and receiver. The beam-matched filter response (time-domain beamforming, LFM processing) is shown in Fig. 3. Numerical Modeling shows that the lowest order axial rays propagate over the ridge, but the next set of deep-water rays interact with the ridge. This is evident in the data where two early arriving paths can be observed as well as a significant amount of scattered energy (scattered in arrival time and bearing). The latter are inferred to have scattered off of the ridge.

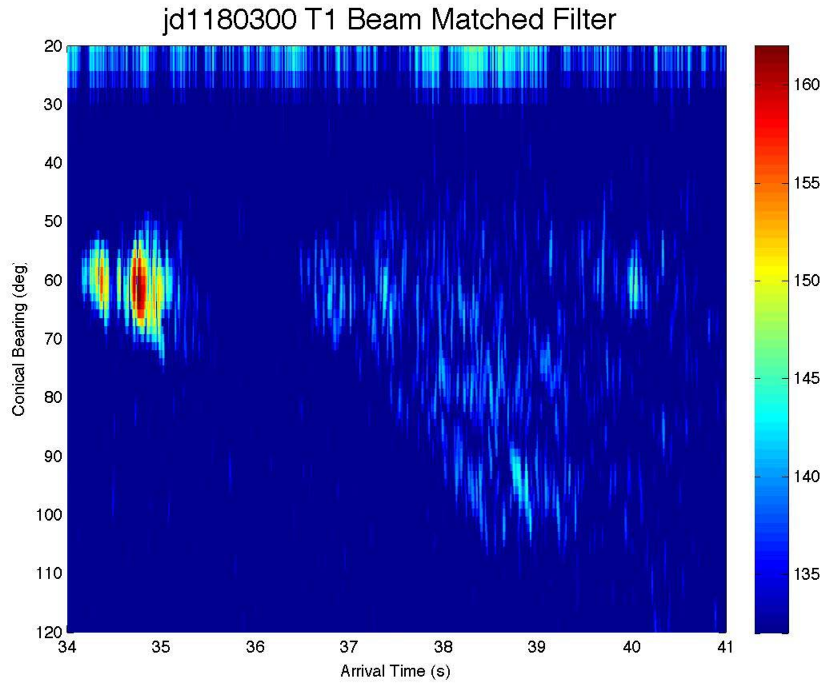

Figure 3. Beam Matched Filter results of LFM from tomographic source T1 showing the deep water propagation paths at 34.5 sec as well as energy scattered from the deep ocean ridge at 37-40 sec.

The final set of results shown here is ambient-noise measurements taken (with the J15 source on actually). Broadband bearing-time-records of the beam-responses are shown in Fig. 4. The presence of 2-4 discrete interferers, in addition to the J15 source, is observed. There is also a evidence of significant diffuse energy, particularly at lower frequencies. This is considered to be more distant intereferers.

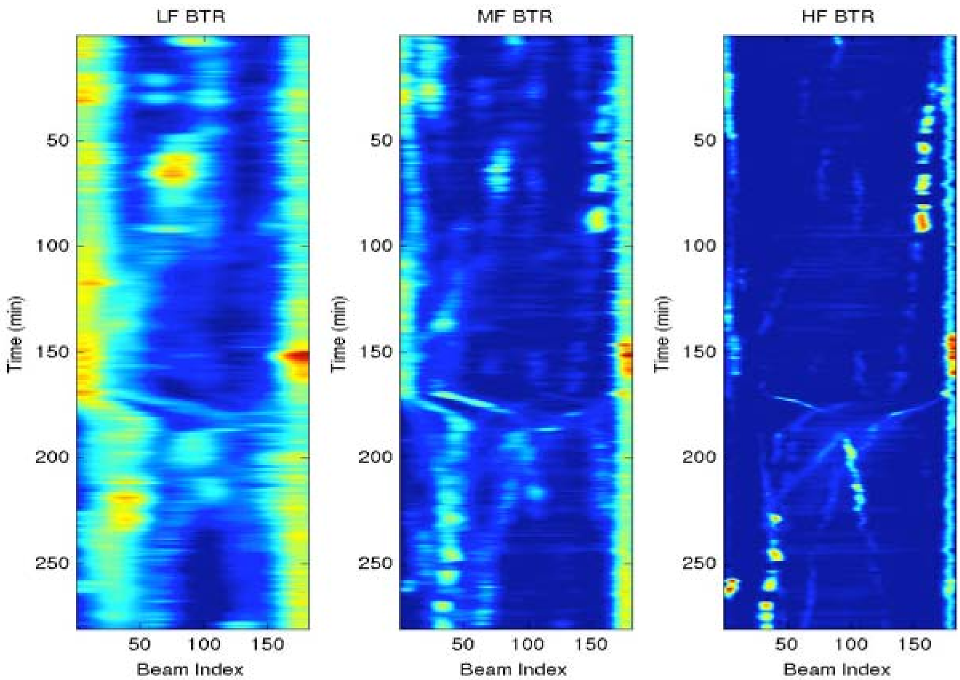

Figure 4. Four hour Ambient Noise Bearing Time Record (BTR), broken into 3 frequency bands: LF(10-50 Hz), MF (55-250 Hz) and HF (250-500 Hz). The R/V Kilo Moana turns at 180 sec. The signal at 50 min (150 deg) is the J15 source. The steady signal at 180 is the ownship noise of the R/V Kilo Moana.

IMPACT/APPLICATIONS

The primary impact of this years work was to collect data in preparation for the 2010 long-term experiment. With this data set successfully in house, plans are being made to use a vertical line array for the PhilSea10 experiment. Estimation of the impact on passive ASW detection approaches will require processing of the PhilSea09 data – an FY10 task.

TRANSITIONS

Although no specific transition paths have yet been identified for this work, the scientific findings can be incorporated in current deep-water passive detection approaches (via IWS5, APB).

RELATED PROJECTS

This project is related to the ONR RAP program, with emphasis on the structure of deep-water ambient noise and on the stability of bottom bounces propagation.

REFERENCES and PUBLICATIONS

1. K. D. Heaney, Journal of the Acoustical Society of America **126** (3), 1036-1045 (2009).
2. K. D. Heaney and J. J. Murray, Journal of the Acoustical Society of America **125** (4), 1394-1402 (2008).